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AN ARCHIPELAGO OF SAND DUNES IN A LAKE OF CENTRAL ASIA.

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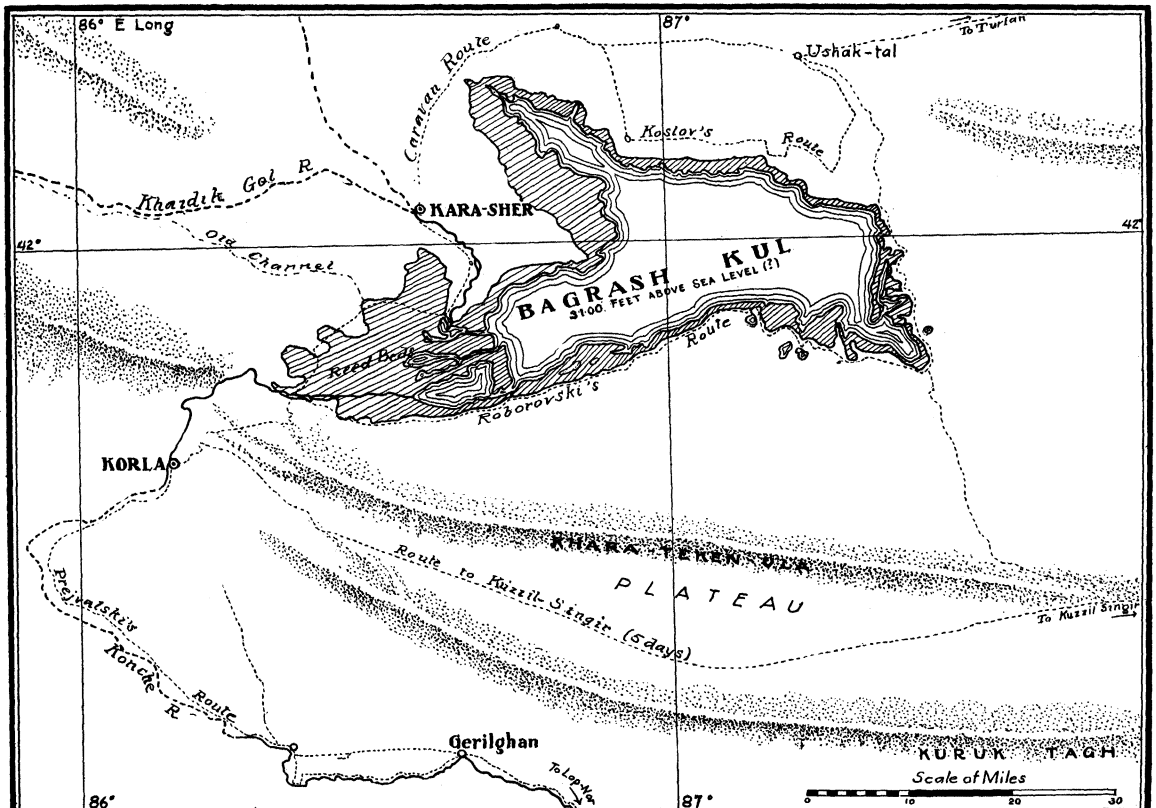
The continent of Asia is singularly deficient in lakes of the so-called normal type—bodies of fresh water like Lake Superior, having outlets to the sea or to some other lake, and occupying *grabens* or depressions due to movements of the earth's crust. Lake Baikal is the only large body of water of this sort. Three other fresh water lakes of moderate size lie like Baikal in grabens in the plateaux which form the backbone of Asia, but none of these drain to the sea, and all possess peculiar characteristics. The Armenian lake, Gokcha, nearly fifty miles long, is almost normal, having an outlet to the Caspian Sea much of the time. In dry periods, however, it often fails to overflow for several years. Another lake, Issik Kul, in the Tian Shan region, 115 miles long, appears on the map to have an outlet leading northwest into the desert toward the Sea of Aral. As a matter of fact the apparent outlet is really an inlet. The Chu river, the largest stream of the region, flows northward almost to the western end of Issik Kul, and there divides. One branch flows eastward into the lake, and the other northwestward to be lost in the desert. The divided stream presents the appearance of an outlet on the map, and in times of unusually high water actually serves as such. The third lake, Bagrash Kul, 55 miles long, forms the subject of the present article. Like Lakes Gokcha and Issik Kul, it has sometimes overflowed and sometimes failed to do so. At present it appears to have discharged through the Konche river to the swampy salt lake of Lop-Nor for a long term of years.

Bagrash Kul is situated not far from the centre of Asia in the



BAGRASH KUL, A LAKE IN CENTRAL ASIA.

latitude of Chicago, and about as far east of Greenwich as the American city is west of that point. It lies in a graben at an elevation of about 3,000 feet above the sea and about 9,000 feet below the broad uplands and swelling ranges of the Tian Shan plateau. The plateau, here at its eastern end, breaks up, as it were, into several eastward-pointing fingers between which lie the deep depressions of Bagrash Kul, and Turfan. East and west the graben of Bagrash Kul extends about seventy-five miles, and north and south over fifty. Westward it narrows gradually to the valley of the Khaidik Gol river, the main affluent of the lake. On the north and south it appears to be bounded by faults of comparatively recent date. This is proved by physiographic rather than stratigraphic evidence, for the stratigraphy has never been studied. On the south the finger of Tian Shan, which there hems in the graben, is seen from below to be comparatively flat-topped, and the natives describe it as like the more western parts of the plateau, a region of broad plains and gently-sloping mountains of mature topography, the summer home of a few truculent Mongol nomads. It is bordered by a very steep escarpment, cut into enormous buttresses by deep narrow cañons. The foot of the escarpment is comparatively straight, without projecting spurs or deeply reentrant fans of gravel. The valleys are narrow clear to the point where they suddenly debouch upon the open floor of the graben. On the north much the same condition prevails. Here, however, in the neighborhood of Ushak Tal it can be seen that the inferred fault line at the base of the escarpment cuts diagonally across the strata of the mountains, a conformation which almost certainly indicates faulting. Eastward the graben has no distinct boundary, but merges imperceptibly into the so-called Kuruk Tagh, or Dry Mountains, a region of intense aridity characterized by vast deposits of gravel half burying maturely dissected mountains, and coming to an end in the broad salt plains of ancient lakes now extinct. Apparently, this eastern region, with its gentle slopes and its abundant evidences of prolonged erosion under nearly the same conditions as those now prevailing, represents the state of the Tian Shan plateau before it was uplifted.

Young fault scarps are found, not only at Bagrash Kul, but at Turfan, a hundred miles to the northeast, Issik Kul, four hundred miles to the west, the Lop basin, three hundred miles to the south, and apparently in other parts of Central Asia. In every case the faults are associated with broadly uplifted regions of mature topography. It seems safe to infer that the prevalent form of mountain-building in recent times throughout a large part of the great central

mountain masses of Asia has been by the uplift of extensive plateaux, bounded in many cases by faults and elsewhere by flexures, and broken often by grabens.

Coming to the floor of the graben of Bagrash Kul, we find that on every side it is bordered for a space of from five to twenty miles by the piedmont gravel slopes, which form such a characteristic feature of all arid mountain regions. At the base of the escarpments the gravel is coarse and bears but little vegetation, partly because the rainfall is scanty, and partly because water sinks into the gravel very rapidly. Farther out from the mountains the gravel gives place to sand and silt and the amount of vegetation increases. On the west, where the Khaidik Gol river brings down a great amount of waste, a large fan or delta of fine material has ben built, pushing the lake far to the east, and dividing it into two distinct arms. Most of the population of the region gathers on the delta, for here there is the greatest amount of water for the irrigation, without which no crops can be raised. On the river lies the town of Kara Sher, with about 5,000 inhabitants, partly Chantos of Aryan race, Turkish speech, and Mohammedan faith, and partly Dungans, or Mohammedan Chinese. Around the city there are numerous villages, which appear as groups of trees towering above mud walls in the midst of fertile grain fields. At a distance from the river, where no water can be procured for irrigation, the plain is covered with a fine growth of tall pampas grass, rising occasionally above the head of a rider on horseback, and giving to the region an appearance of habitability rare in the dry inner parts of Asia. Here and there in the midst of the tall grass one spies groups of the round, gray felt tents of Mongol nomads, who feed their flocks and herds on the delta in winter and go to the grassy uplands of the plateau in summer. They get water during the winter from wells, which can easily be sunk in the soft silt of the delta.

A glance at the map of the lake shows that its shore-line is very irregular, as though the coast had been drowned. This is especially noticeable at the eastern end, where numerous promontories and islands and deep bays present an appearance not unlike that of the coast of Maine or Norway. As one approaches the eastern end of the lake from the south, he finds four zones between the fault scarp at the base of the plateau and the edge of the water. First, on the outside there are the piedmont gravels streaming down from the mountains on every hand; then comes a somewhat saline belt of fine yellow silt, only a mile or so wide on the south, but stretching six or seven miles east of the lake, and there becoming so saline that edible

salt is collected from it for use at Kara Sher; third, there is a belt of great sand dunes, trending north-northeast with the steeper slope to the east, tawny yellow in the main, but dark gray on the outer edges, where sand has been blown in from the gravel; and fourth, the lake is bordered by a belt of thick, tall reeds ending suddenly at the water's edge in a perpendicular bank rising three to six inches high above the surface and descending three or four feet below it. The dunes appear to be stationary in their lower parts, for up to a height of 100 feet or more they bear a peculiar kind of grass found most frequently in dry lake-beds. In addition to the grass there are other small weeds and bushes which appear to have sprung up since the sand ceased to move. The upper parts of the dunes are free from vegetation, and seem to move this way and that with the wind. Although, as said above, the main declivity is to the east, indicating that the strongest winds are from the west, yet in February, 1906, the upper parts of the dunes had been blown back so that the steepest slope for ten or twelve feet was toward the west, suggesting that recent winds had been strong from the east. In many places dead vegetation is found well above the limit of present growth, which may be due to the recent change of climate, of which there is evidence in the ruins found on the north side of Bagrash Kul. The dunes are limited to the eastern end of the lake, where they form a belt from three to five miles wide, extending thirty or more miles along the south shore, and half as far on the east shore. They are highest ten or twenty miles from the eastern end, where, close to the south shore, the writer climbed one having a height of 550 feet, a small mountain of pure sand.

The most remarkable feature of the sand dunes is that some of them stand directly in the water as islands, while others form great promontories. The scenery is in the highest degree unique. Climbing to the top of a giant sand dune, one finds himself on an island of tawny sand a mile or two long and half a mile wide. Round about there is a fringe of dull brown reeds, while outside the reeds, as the scene was in February, there lies a white expanse of ice covered with an inch or two of snow. Lakeward only the ice and snow are visible. Landward narrow gulfs stretch inland for two or three miles, twisting this way and that among hilly islands or between high promontories of soft sand. Here and there one sees islands in the lake, or, in the other direction, sheets of water apparently completely surrounded by sand. In many places the lowland between the mountains of sand is covered with miles of reed beds. In spring, when the reeds begin to sprout and the lake is free from ice, the

scenery must be wonderful. A lake of the deepest blue then borders strips of vivid green, within which the paler, gray-green vegetation of the base of the dunes gradually shades into the pale reddish yellow of lofty sand hills, while far away beyond the shimmering white of the salt plains and the monotonous gray of the zone of piedmont gravel, pale blue mountains rise capped with glistening snow.

Hedin, following Roborowski, believes that this archipelago of sand dunes accumulated when the lake stood at its present level. He supposes that the sand was blown across the water. This appears to be impossible. In the first place, several of the largest dunes are complete islands, separated from the main land by an open channel 1,000 feet wide, and by reed beds two or three miles wide. The huge quantities of sand in the islands could hardly have crossed such areas without building up the reed beds into dunes. In the channels the depth of water is considerable. In one case half a mile in from the mouth of one of the large bays, and 500 feet from the shore of one of the larger islands, the writer chopped through 21 inches of ice, and found the depth of the water to be 29 feet 9 inches. This shows that even at low water there can be no very complete connection between the mainland and this particular dune. The depth of the lake as a whole is not known. At the narrowest point southeast of the tip of the Khaidik Gol delta a depth of 34 feet 9 inches was found about half way from shore to shore.

Another line of reasoning shows more conclusively that the sand was not blown to the islands while they were surrounded by water. The prevalence of the steepest slope of the dunes on the east or southeast side indicates almost beyond question that the sand came from the north and west. That is, it came across what is now the bed of the lake. It certainly could not have done so if the lake bed were covered with water, as it now is. Therefore, we must conclude that at some former time the lake was dry for a long period, during which its bed was subjected to æolian erosion, and great deposits of sand were piled up along the eastern and southern shores.

In endeavoring to find the cause of the laying bare of the lake bed, one of the first suggestions is that Bagrash Kul, like Issik Kul, may have been tilted so that the water was poured from the western end into the eastern end, drowning the valleys and giving the magnificent scenery there found. This is negatived, however, by the fact that the western shores are not smooth like those of Issik Kul, as befit an uplifted portion of a lake bed, but are sinuous, as if they, too, had been drowned. Moreover, it would require a very great amount of tipping to remove the water sufficiently to

allow the wind to gather the mass of sand found in the dunes. Another suggestion is that the lake may have diminished in size during some of the interglacial epochs of which there is evidence among the moraines of Tian Shan. It is probable that the climate was drier at such times, and this may have been a contributory cause of the accumulation of sand, but it is not probable that the climate was so extraordinarily dry as to cause the almost complete disappearance of the lake. It is more likely that the drying up of Bagrash Kul was due to the diversion of the Khaidik Gol river, so that, without emptying into the lake, it flowed directly to the gorge at Korla, by which the Konche river now carries the waters of Bagrash through the southern finger of the Tian Shan plateau. Travellers report an old channel running in this direction. The Chu river, as we have seen, does practically the same thing at present. Most of its water flows off through a gorge in the mountains northwest of Issik Kul without entering the lake. In Seyistan, in eastern Persia, the Helmund river is known to have done likewise some centuries ago, flowing to the God-i-Zirrah instead of to the Hamun-i-Seyistan, as it now does. Apparently, in arid regions, where rivers build up fans with great rapidity, it is no uncommon thing for the main tributary of a lake to be diverted. Changes in the course of streams would be especially likely to happen in times of extreme aridity like interglacial epochs. At the beginning of such epochs the rivers would be very heavily loaded with waste, because the gradual death of vegetation on the mountain sides, as the climate became drier, would allow the rock mantle to be quickly stripped off. Accordingly, fans would accumulate rapidly, and the rivers would be forced to take new courses.

It is probable that the deflection of the Khaidik Gol took place during an epoch of great aridity, for otherwise the lake-bed would have been covered with vegetation, and the winds would have had no opportunity to accumulate large amounts of sand. The period or periods during which the lake was dry must have been prolonged, for dunes over 500 feet high cannot be formed in a short time. Nevertheless, the river must have flowed into the lake for even longer periods, for otherwise it could not have formed so large a delta. Lake Bagrash Kul, with its drowned archipelago of sand dunes and its deflected river, furnishes a good illustration of the number and variety of the vicissitudes to which even a so-called normal lake is subject in an arid climate.